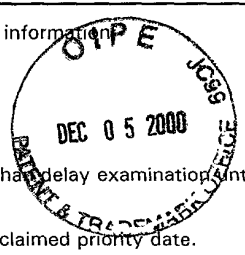


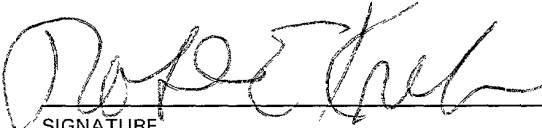
FORM-PTO-1390 (Rev. 12-29-99)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER <div style="text-align: right; font-family: cursive; font-size: 1.2em;">       C. Burt        12/19/00     </div>
<b>TRANSMITTAL LETTER TO THE UNITED STATES          DESIGNATED/ELECTED OFFICE (DO/EO/US)          CONCERNING A FILING UNDER 35 U.S.C. 371</b>			025219-289 U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/700,182
INTERNATIONAL APPLICATION NO. PCT/FR99/01119	INTERNATIONAL FILING DATE 11, May, 1999 (11.05.99)	PRIORITY DATE CLAIMED 12, May, 1998 (12.05.98)	
TITLE OF INVENTION PROCESS FOR WRITING BRAGG GRATINGS, APPARATUS FOR THE USE OF THIS PROCESS AND BRAGG GRATING DEVICES OBTAINED BY THIS PROCESS			
APPLICANT(S) FOR DO/EO/US Pierre FERDINAND, Sylvain MAGNE and Christophe MARTINEZ			
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:			
<div style="display: flex; justify-content: space-between;"> <div style="width: 80%;"> <ol style="list-style-type: none"> <li>1. <input type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>2. <input checked="" type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>3. <input type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and the PCT Articles 22 and 39(1).</li> <li>4. <input type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.</li> <li>5. <input type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))               <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).</li> <li>b. <input type="checkbox"/> has been transmitted by the International Bureau.</li> <li>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US)</li> </ol> </li> <li><input type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)).</li> <li><input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))               <ol style="list-style-type: none"> <li>a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).</li> <li>b. <input type="checkbox"/> have been transmitted by the International Bureau.</li> <li>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li>d. <input type="checkbox"/> have not been made and will not be made.</li> </ol> </li> <li>8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</li> <li>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</li> <li>10. <input type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</li> </ol> <p>Items 11. to 16. below concern other document(s) or information included:</p> <ol style="list-style-type: none"> <li>11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</li> <li>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</li> <li>13. <input type="checkbox"/> A FIRST preliminary amendment.  <input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment.</li> <li>14. <input type="checkbox"/> A substitute specification.</li> <li>15. <input type="checkbox"/> A change of power of attorney and/or address letter.</li> <li>16. <input type="checkbox"/> Other items or information:</li> </ol> </div> <div style="width: 15%; text-align: center;">  </div> </div>			

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FORM-PTO-1390 (Rev. 12-29-99)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER
<b>TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371</b>			025219-289
			U.S. APPLICATION NO. (if known, see 37 C.F.R. 1.5) Unassigned <b>09/700182</b>
INTERNATIONAL APPLICATION NO. PCT/FR99/01119	INTERNATIONAL FILING DATE 11, May, 1999 (11.05.99)	PRIORITY DATE CLAIMED 12, May, 1998 (12.05.98)	
TITLE OF INVENTION PROCESS FOR WRITING BRAGG GRATINGS, APPARATUS FOR THE USE OF THIS PROCESS AND BRAGG GRATING DEVICES OBTAINED BY THIS PROCESS			
APPLICANT(S) FOR DO/EO/US Pierre FERDINAND, Sylvain MAGNE and Christophe MARTINEZ			
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:			
1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371. 2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371. 3. <input type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and the PCT Articles 22 and 39(1). 4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date. 5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2)) a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau). b. <input checked="" type="checkbox"/> has been transmitted by the International Bureau. c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US) 6. <input checked="" type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)). 7. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)) a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau). b. <input type="checkbox"/> have been transmitted by the International Bureau. c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired. d. <input type="checkbox"/> have not been made and will not be made. 8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)). 9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). 10. <input type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)). Items 11. to 16. below concern other document(s) or information included: 11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98. 12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. 13. <input checked="" type="checkbox"/> A FIRST preliminary amendment. <input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment. 14. <input type="checkbox"/> A substitute specification. 15. <input type="checkbox"/> A change of power of attorney and/or address letter. 16. <input checked="" type="checkbox"/> Other items or information: PCT Request, International Search Report and cited references			

U.S. APPLICATION NO. (If known / see 37 C.F.R. 1.50) Unassigned		INTERNATIONAL APPLICATION NO. PCT/FR99/01119		ATTORNEY'S DOCKET NUMBER 025219-289	
17. <input checked="" type="checkbox"/> The following fees are submitted:				<b>CALCULATIONS</b>	PTO USE ONLY
<b>Basic National Fee (37 CFR 1.492(a)(1)-(5)):</b>  Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... \$1,000.00 (960)  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... \$860.00 (970)  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... \$710.00 (958)  International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... \$690.00 (956)  International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) ..... \$100.00 (962)					
<b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>				\$ 860.00	
Surcharge of \$130.00 (154) for furnishing the oath or declaration later than months from the earliest claimed priority date (37 CFR 1.492(e)). 20 <input type="checkbox"/> 30 <input type="checkbox"/>				\$ 0.00	
Claims	Number Filed	Number Extra	Rate		
Total Claims	12 -20 =	0	X\$18.00 (966)	\$ 0.00	
Independent Claims	1 -3 =	0	X\$80.00 (964)	\$ 0.00	
Multiple dependent claim(s) (if applicable)			+ \$270.00 (968)	\$ 0.00	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$ 860.00	
Reduction for 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				\$ 0.00	
<b>SUBTOTAL =</b>				\$ 860.00	
Processing fee of \$130.00 (156) for furnishing the English translation later than months from the earliest claimed priority date (37 CFR 1.492(f)). 20 <input type="checkbox"/> 30 <input type="checkbox"/>				\$ 0.00	
<b>TOTAL NATIONAL FEE =</b>				\$ 860.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 (581) per property +				\$ 0.00	
<b>TOTAL FEES ENCLOSED =</b>				\$ 860.00	
				Amount to be: refunded	\$
				charged	\$
a. <input checked="" type="checkbox"/> A check in the amount of \$ <u>860.00</u> to cover the above fees is enclosed. b. <input type="checkbox"/> Please charge my Deposit Account No. <u>02-4800</u> in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed. c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>02-4800</u> . A duplicate copy of this sheet is enclosed.  <b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</b>					
SEND ALL CORRESPONDENCE TO:  Robert E. Krebs, Esq. BURNS, DOANE, SWECKER & MATHIS, L.L.P. P.O. Box 1404 Alexandria, Virginia 22313-1404 (650)622-2300					
 SIGNATURE				Robert E. Krebs NAME	
<u>25,885</u> REGISTRATION NUMBER					

Patent  
Attorney's Docket No. 025219-289

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In re Patent Application of )  
)  
Pierre FERDINAND et al. ) Group Art Unit: Unassigned  
)  
Application No.: Unassigned ) Examiner: Unassigned  
)  
Filed: Herewith )  
)  
For: PROCESS FOR WRITING BRAGG )  
GRATINGS, APPARATUS FOR THE )  
USE OF THIS PROCESS AND )  
BRAGG GRATING DEVICES )  
OBTAINED BY THIS PROCESS )

**PRELIMINARY AMENDMENT**

Assistant Commissioner for Patents  
Washington, D.C. 20231

Sir:

Prior to examination of the subject application, please amend the application as follows:

**IN THE CLAIMS:**

Please cancel original Claims 1-12.

09/700182-120500

PLEASE ADD THE FOLLOWING CLAIMS:

13. Process for writing a Bragg grating in a transparent substrate (36) forming a light guide, particularly in an optical fiber, the Bragg grating forming a spectral filter with regard to a light wave that passes through it, process according to which the interference pattern between two light beams (28, 30) with the same wavelength and coherent with each other but with angular offset, is transferred directly into the substrate due to a photosensitivity phenomenon within the same said substrate, this interference pattern being transferred in the substrate in the form of a modulation of the refraction index of this substrate, this process being characterized in that a phase splitter with an adjustable position and orientation is used to divide at least one of the said light beams into at least two sub-beams, creating a phase shift between the two sub-beams and generating a corresponding phase shift in the Bragg network.

14. Process according to Claim 13, in which the interference pattern is transferred according to an amplitude separation configuration.

15. Process according to Claim 13, in which the interference pattern is transferred according to a wave front separation configuration.

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16. Process according to Claim 13, in which the position of the phase shift or the value of this phase shift or the position and value of this phase shift in the light beam formed by the two sub-beams, can be modified with time.

17. Apparatus for use of the writing process according to Claim 13, this apparatus being characterized in that it comprises:

- at least one phase splitter (42) capable of creating a phase shift between at least two sub-beams, due to a difference in the optical path, and
- a means (61) of adjusting the position of the phase splitter, this adjustment means having at least two degrees of freedom, one being angular degree of freedom provided for adjustment of the value of the phase shift, and the other being a translation degree of freedom provided for adjustment of the position of the phase shift in the light beam formed by the two sub-beams.

18. Apparatus according to Claim 17, also comprising interferometric means with two or three mirrors (32, 34) for transferring the interference pattern according to an amplitude separation configuration.

19. Apparatus according to Claim 17, also comprising interferometric means with a prism (46) or a Lloyd folded mirror (64) for transferring the interference pattern according to a wave front separation configuration.

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20. Phase skip Bragg grating with high spectral selectivity obtained by the process according to Claim 13, the phase shift between the two sub-beams advantageously being equal to  $\pi$ .

21. Bragg grating obtained by the process according to Claim 13, this Bragg grating being identical to a pre-written Bragg grating and being written on this pre-written grating, at the same position, with a phase change of  $\pi$  over the entire length of the pre-written grating, to erase all or some of the original grating in order to obtain a given reflection coefficient,

22. Fabry-Perot cavity delimited by two Bragg gratings at different positions in space, these two Bragg gratings being obtained by the process according to Claim 13,

23. Bragg grating with a determined index modulation envelope, particularly an apodized Bragg grating, obtained by the process according to Claim 13, by successively writing two Bragg gratings comprising parts in phase opposition, the time taken to overwrite one Bragg grating by the other being variable, to give a variable phase shift and a variable value of the phase shift.

24. Bragg grating according to Claim 23, the position of the phase shift being displaced by a programmable movement.

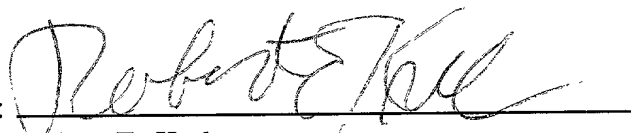
**REMARKS**

The claims of the subject application have been amended to avoid multiple dependency. Favorable consideration of this application is respectfully requested.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

By: \_\_\_\_\_



Robert E. Krebs  
Registration No. 25,885

P.O. Box 1404  
Alexandria, Virginia 22313-1404  
(650)622-2300

Date: November 9, 2000

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6/PRTS

PROCESS FOR WRITING BRAGG GRATINGS, APPARATUS FOR  
THE USE OF THIS PROCESS AND BRAGG GRATING DEVICES  
OBTAINED BY THIS PROCESS

Technical field

This invention relates to a process for writing Bragg gratings, and an apparatus for the use of this process.

It applies to obtaining a large number of Bragg  
5 grating devices and in particular to the manufacture of  
phase skip Bragg gratings with high spectral  
selectivity, overwriting of one Bragg grating to erase  
it and replace it with another, the manufacture of  
Fabry-Perot cavities and the manufacture of Bragg  
10 gratings with a predefined index modulation envelope,  
both for optical fibers and for integrated optical  
guides.

State of prior art

15 Bragg gratings were first used in optical fibers  
about twenty years ago. Before this time, these  
components were frequently used in the field of  
integrated optics, acousto-optics and in semi-  
conductors, for example in distributed Bragg reflector  
20 lasers.

A conventional Bragg grating behaves like a  
spectral filter with regard to the wave that passes  
through it. It reflects a band of wavelengths with a  
given width (typically a few hundred picometers) around  
25 a central resonance value  $\lambda_B$  called the Bragg  
wavelength. In transmission, by complementarity, the

spectrum of the guided wave loses this same band of wavelengths (see Figure 1 on which the variations of the transmission T of a conventional Bragg grating are represented as a function of the wavelength, where  $\lambda_B =$   
5 1319 nm).

There are many applications for Bragg gratings, mainly for telecommunications (for example for multiplexing, demultiplexing, add-drop devices, distributed feed back lasers). Bragg gratings made  
10 from optical fibers also revolutionized the field of optical fiber sensors due to their role as transducers (for example for temperatures and elongations).

Conventional Bragg gratings are known formed by a simple sinusoidal modulation, for which the spectral  
15 response is given in Figure 1, and advanced Bragg gratings on which the sinusoidal modulation is modified to enable the creation of filters with particular spectral shapes; it is thus possible to improve conventional Bragg gratings depending on the field of  
20 application considered or needs, or even to make new components.

In practice, the production of an advanced Bragg grating requires a process and an apparatus with a number of qualities. The following problems need to be  
25 solved:

- the apparatus must be capable of producing a Bragg grating conform with the required theoretical result,
- the manufacturing process used with the  
30 apparatus must provide access to a number of parameters involved in making Bragg gratings,

- writing two Bragg gratings twice in succession using the same protocol must give the same result,
- the process and the apparatus must be simple and must be useable by anyone working in this field to obtain the required Bragg grating, and
- if it is to be marketable, the apparatus must be inexpensive and must be useable to make various families of Bragg gratings at an inexpensive price.

#### Description of the invention

This invention is designed to solve the above problems.

- The first objective of the invention is an process for writing a Bragg grating in a transparent substrate forming a light guide, particularly in an optical fiber, the Bragg grating forming a spectral filter with regard to a light wave that passes through it, process according to which the interference pattern between two light beams with the same wavelength and coherent with each other but with an angular offset, is transferred directly into the substrate due to a photosensitivity phenomenon within the same said substrate, this interference pattern being transferred in the substrate in the form of a modulation of the refraction index of this substrate, this process being characterized in that at least one of the said light beams is divided into at least two sub-beams offset in phase with respect to each other.

5           According to a second particular embodiment, the interference pattern is transferred according to a wave front separation configuration.

The invention also applies to an apparatus for use of the process according to the invention, this apparatus being characterized in that it comprises:

- The composition of the apparatus according to the invention is very simple, it is easy to adjust and use, and it is very flexible in use.

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mirrors for transferring the interference pattern according to an amplitude separation configuration.

According to a second particular embodiment, this apparatus also comprises interferometric means with a prism or a Lloyd folded mirror for transferring the interference pattern according to a wave front separation configuration.

The invention also relates to:

- 10 - a phase skip Bragg grating with high spectral selectivity obtained by the process according to the invention, the phase shift between the two sub-beams advantageously being equal to  $\pi$ ,
- 15 - a Bragg grating obtained by the process according to the invention, this Bragg grating being identical to a pre-written Bragg grating and being written on this pre-written grating, at the same position, with a phase change of  $\pi$  over the entire length of the pre-written grating, to erase all or some of the original  
20 grating in order to obtain a given reflection coefficient,
- 25 - a Fabry-Perot cavity delimited by two Bragg gratings at different positions in space, these two Bragg gratings being obtained by the process defined in the invention,
- 30 - a Bragg grating with a determined index modulation envelope, particularly an apodized Bragg grating, obtained by the process according to the invention, by successively writing two Bragg gratings comprising parts in phase opposition, the time taken to overwrite one

5 Bragg grating by the other being variable, to  
give a variable phase shift and a variable value  
of the phase shift, for example the position of  
the phase shift being displaced by a  
programmable movement.

Brief description of the drawings

10 This invention will be better understood after  
reading the following example embodiments given for  
information only and in no way restrictive, with  
reference to the attached drawings in which:

- Figure 1, described above, describes  
transmission variations in a conventional Bragg  
grating as a function of the wavelength,
- 15 - Figure 2 diagrammatically illustrates the  
interference diagram for two plane waves with no  
phase splitter,
- Figure 3 diagrammatically illustrates the  
interference diagram for two plane waves in the  
20 presence of a phase splitter,
- Figure 4 diagrammatically illustrates phase  
splitters placed in series,
- Figure 5 diagrammatically illustrates a curved  
phase splitter,
- 25 - Figure 6 diagrammatically illustrates a phase  
splitter formed by a lens,
- Figure 7 diagrammatically illustrates a phase  
splitter with an index change,
- Figure 8 diagrammatically illustrates a phase  
30 splitter inclined with respect to an incident  
light beam,

- Figure 9 diagrammatically illustrates a support device for a phase splitter that could be used in the invention,
- 5 - Figure 10 diagrammatically illustrates an amplitude separation writing process for a phase skip Bragg grating according to the invention, for an assembly with transverse irradiation,
- 10 - Figure 11 diagrammatically illustrates a wave front separation writing process for a phase skip Bragg grating according to the invention, using the prism method,
- Figure 12 diagrammatically illustrates another wave front separation writing process for a phase skip Bragg grating according to the invention, using a Lloyd mirror,
- 15 - Figure 13 shows variations in the transmission of a phase skip Bragg grating as a function of the wavelength,
- Figure 14 diagrammatically illustrates a partial double reflection in a Bragg grating around a phase change due to a cavity,
- 20 - Figure 15 diagrammatically illustrates propagative and counter-propagative coupling in a phase skip Bragg grating,
- 25 - Figure 16 diagrammatically illustrates an example of an index modulation with linear envelope, and
- Figure 17 diagrammatically illustrates an example of an index modulation apodized by a Gaussian curve.
- 30

### Detailed description of particular embodiments

According to this invention, interference is generated with one or a plurality of phase shifts by means of one or a plurality of optical phase shifting  
5 elements or phase splitters.

The first step (Figure 2) is the simple case of two plane light waves  $O_1$  and  $O_2$ , output from the same light beam and with no phase splitter. The electrical fields for these two waves are denoted  $\vec{E}_1$  and  $\vec{E}_2$ , the  
10 corresponding wave planes are denoted  $P_1$  and  $P_2$  and the corresponding wave vectors are denoted  $\vec{k}_1$  and  $\vec{k}_2$ . The modulus of  $\vec{k}_1$  and  $\vec{k}_2$  is denoted  $k$ , and the modulus of  $\vec{E}_1$  and  $\vec{E}_2$  is denoted  $\xi_0$ . The intensity  $I(z)$  resulting from the interference of these two waves on the  $Oz$  axis  
15 in Figure 2 is therefore in the form:

$$I(z) = 2\xi_0^2 \cdot [1 + \cos(2k \sin(\Psi) \cdot z)]$$

The period of the modulation thus created depends on the angle  $\Psi$  between the wave vectors  $\vec{k}_1$  and  $\vec{k}_2$  and the axis of observation  $OZ$  of the interference fringes.

20 The sequence of dark and light fringes can be transferred in a wave guide by a photosensitive phenomenon, the efficiency of which depends on many parameters, for example such as the type of material used in the guide, the power of the writing beams, and  
25 the exposure time. Thus a Bragg grating can be written in the guide.

We will now consider interference between these two waves when a phase 2 splitter is located on the path of the wave  $O_2$  parallel to the plane of wave  $P_2$   
30 according to the invention. We will use the same



notation as above, considering the effect of the splitter on  $\vec{E}_2$  (Figure 3).

Two zones I and II corresponding to two parallel sub-beams formed by the wave  $O_2$  after it has passed through the splitter 2, which is thicker in the part facing area II than in the part facing area I. The intensity  $I(z)$  then becomes:

$$I(z) = 2\xi_0^2 \cdot (1 + \cos(2k \sin(\Psi) \cdot z)) \text{ for } 0 < z < z_t$$

$$I(z) = 2\xi_0^2 \cdot (1 + \cos(2k \sin(\Psi) \cdot z + \Delta\Phi)) \text{ for } z_t < z < z_f$$

The phase change or shift  $\Delta\Phi$  introduced by the phase splitter in one of the two beams associated with the waves then takes place in the intensity modulation that will generate the Bragg grating.

On Oz, the phase change abscissa is determined by the relative position of the splitter 2 with respect to beam  $O_2$ . Therefore, this abscissa  $z_t$  can be modified very easily by the splitter translating along a y axis parallel to this splitter. It can be seen that the interference area is delimited by the abscissas 0 and  $z_f$  on the Oz axis.

The value  $\Delta\Phi$  is determined by the difference in optical path in the splitter between areas I and II. This splitter can be made such that  $\Delta\Phi = \pi$ . Furthermore, this value can be modified very simply by rotating the splitter at an angle  $\theta$  to incline this splitter with respect to beam  $O_2$ .

According to the invention, two waves with multiple phase changes can also be made to interfere; in the same way as a phase splitter comprising a step

induces a phase shift in the interference pattern as shown in Figure 3, a series of splitters 4, 6, 8 placed in sequence can be placed in one  $O_3$  of the two interfering beams (for example ultraviolet beams) (Figure 4). The result is then an interference pattern with a series of phase changes corresponding to steps 10, 12, 14 in splitters 4, 6, 8 respectively.

Another solution is to combine this series of splitters into a single splitter that induces a series of phase shifts by multiple changes in the optical path (stepped splitter).

We will now explain the production of a phase splitter. The material from which this splitter is made must be transparent to the wavelength(s) that will be used to write the Bragg grating by photosensitivity in a light guide.

In the following, the production of a single phase change splitter is described, but splitters with several phase changes could be made in a similar manner.

The splitter, or the element creating the optical phase shift that is the easiest to make and the most practical to use has a parallelepiped shape. When this type of splitter is inserted in a beam, the input wave front also appears at the output, but there are one or several additional phase shifts due to at least two different optical paths (Figure 3).

For some applications of the invention, it may be necessary to use a non-parallelepiped shaped splitter in order to adapt the configuration of this splitter to the wave front of the beam for which the phase is to be

shifted. For example, it may be necessary to make a phase change without changing the propagation characteristics of a non-parallel beam in which the splitter is inserted; for example (Figure 5) a  
 5 splitter 9 delimited by two coaxial cylindrical faces 11 and 13 can be made; due to the optical path transition symbolized by line 15, a splitter of this type placed in a beam that converges on the axis common to the faces, induces a phase shift on the beam as  
 10 shown in the example in Figure 3.

A phase change may also be necessary with a change in the beam propagation characteristics. For example, this could be done using a lens that could be considered as a non-parallelepiped shaped splitter.  
 15 The phase change is then inserted using the same principle as above. A cylindrical lens 16 can be seen in the example in Figure 6, that focuses a beam while applying a phase skip to it due to the transition of the optical path symbolized by line 17.

20 The phase skip in the splitter can be obtained by changing its thickness. This can be done by etching one or several parts of the splitter or by depositing one or several layers on one or several parts of the splitter. For example, considering a splitter with two  
 25 areas with thicknesses  $e_1$  and  $e_2$  respectively, the wave front is deformed after passing through the splitter due to the phase shift  $\Delta\Phi = (2\pi / \lambda) (n - 1) (e_2 - e_1)$  where  $n$  is the index of the material from which the splitter is made and  $\lambda$  is the wavelength of the beam  
 30 that passes through it.

Thus, a splitter with a thickness  $e_2$  can be used that is inserted in a certain beam thickness perpendicular to the wave planes of the beam (hence  $e_1 = 0$ ).

5 The wave propagation index in one or several parts of the splitter can also be modified to induce one or several optical path changes and therefore one or several phase skips. For example, consider a splitter with thickness  $e$  and index  $n$ . If the index becomes  $n'$  10 for a thickness  $e'$  as shown in Figure 7, the result will be  $e'(n'-n) = (2k+1)\lambda / 2$  (where  $k$  is an integer number). However, when the splitter is inclined (in order to adjust the phase shift), the two beams do not "see" the same index and therefore will be deviated 15 differently. Therefore, a phase splitter with an index change at normal incidence should be used.

In the case of a splitter with a thickness change, different phase shift values can be obtained by changing the inclination angle  $\theta$  of the splitter with 20 respect to the beam without inducing any angular separation. The inclination or rotation may be made about an axis A (Figure 8) parallel to the edges of the step that delimits the phase skip, or about an axis B perpendicular to the edges of the step and in a plane 25 parallel to the two faces of the splitter.

The phase shift can be written as follows as a function of  $\theta$  and  $\theta'$  where  $\theta' = \arcsin(\frac{\sin\theta}{n})$ , where  $\Delta e = e_2 - e_1$  is the thickness of the deposit:

$$\Delta\Phi = \frac{2\pi}{\lambda} \cdot \Delta e \cdot \left[ \frac{n}{\cos\theta'} - \frac{1}{\cos\theta} + \sin\theta \cdot (\tan\theta - \tan\theta') \right]$$

For example, molten silica can be deposited on an optical quality molten silica splitter (surface quality =  $\lambda/10$ ) for use at  $\lambda = 244$  nm. The order  $k$  is chosen to be 4 to obtain a variation of  $\pm\pi$  of the initial value of the phase shift (equal to  $\pi$ ) for an angular variation of  $\pm 45^\circ$ . Therefore, the thickness  $\Delta e = e_2 - e_1$  of the deposit will be:

$$(2k + 1) \frac{\lambda}{2(n-1)} = 2.15 \text{ } \mu\text{m}$$

where  $n = 1.51148$  at 244 nm.

Figure 9 shows a device 18 supporting a phase splitter 20 used to insert the phase splitter in a beam. This device comprises adjustment means that provide it with various degrees of freedom. The stacking order of these adjustment means is arbitrary. For the example shown, Figure 9 shows six adjustment means 19-1 to 19-6 corresponding to six degrees of freedom  $\alpha$ ,  $\beta$ ,  $\theta$ ,  $y$ ,  $z$  and  $x$  (« $y$ », « $z$ » being the translations along the  $y$  and  $z$  axes perpendicular to each other; « $x$ » being the translation along the  $x$  axis perpendicular to each of the  $y$  and  $z$  axes; and « $\alpha$ », « $\beta$ » and « $\theta$ » being the rotations about axes parallel to  $y$ ,  $z$  and  $x$  respectively). However, the support device may have more or less degrees of freedom depending on the configuration of the splitter and the wave front of the incident beam, and depending on the interferometric setup in which it is to be inserted (for example  $z$  is not essential).

In order to facilitate the use of the support device, one or several adjustment means are connected to one or several software controlled motors.

For example, a parallelepiped-shaped splitter can be adjusted based on five degrees of freedom:

- $\alpha$  and  $\beta$  to keep the material change edges vertical, that can also be achieved by construction,
- $x$  to position the splitter in the beam,
- $\theta$  to adjust the phase shift value,
- $y$  to adjust the position of the phase skip in the Bragg grating.

We will now consider how a device according to the invention can be inserted in an interference type setup. We decided to present Bragg grating writing setups made of optical fibers (for example fibers for which the core is doped with  $\text{GeO}_2$ ), but the invention is also applicable to writing gratings in integrated optical guides.

In the following examples, different configurations of interference setups are shown with the insertion of a phase splitter device in order to introduce a single phase change in a Bragg grating. Two writing configurations of a Bragg grating are considered. The first is an amplitude separation configuration in which the two beams are separated for energy but keep the same shape. The second is a wave front separation configuration.

We will distinguish two setups for the amplitude separation configuration. The first corresponds to the holographic setup described in document (10) which, like the other documents mentioned later, is mentioned at the end of this description.

The second setup corresponds to a setup with three mirrors (see document (1)). In both cases, a separating splitter 24 (Figure 10) divides a light beam 26 into two identical beams 28 and 30. An  
 5 interferometric system with two or three mirrors (two mirrors 32 and 34 in the example in Figure 10) superposes these two beams 28 and 30 that form a given angle  $\Psi$ , at the fiber 36. The interferences thus created write the grating in the fiber by cylindrical  
 10 focusing lenses 38 and 40. The phase splitter 42 needs to be placed in one of the two interfering beams.

In general, the disadvantage of the amplitude separation setup is due to the fact that the phase splitter has to be adjusted each time that the Bragg  
 15 wavelength is modified since the orientation of the insolation beam is modified. In order to overcome this disadvantage, the splitter support device (not shown) must be controlled along degrees of freedom  $y$  and  $\theta$  (see above) by a program that takes account of the  
 20 setup beam movements necessary for adjustment of the Bragg wavelength.

We will now consider wave front separation configurations, and firstly an interferometric setup with a prism. Note that the method of separating the  
 25 wave front has the advantage that the phase splitter can be placed immediately after the beam expansion system before the wave front separation. An important advantage of this configuration is that the phase shift can be adjusted by rotating the splitter independently  
 30 of the Bragg wavelength adjustment that is obtained by rotating the interferometric system.

The prism writing method (see document (8)) is diagrammatically illustrated in Figure 11 in which an extended beam 44 is "folded on itself" by reflection on a face of the prism 46. In Figure 11, the reference 48 shows a cylindrical lens. It can be seen that the determination of the Bragg wavelength fixed by the inclination of the two interfering beams, can be adjusted by rotating the prism, against which the fiber 36 is placed. If this rotation is made about an axis perpendicular to the plane of the Figure and passing through the phase skip projected in the optical fiber, then the phase splitter 42 placed on the trajectory of the beam 44 in front of lens 48, does not need to be adjusted for the different prism positions.

A wave front separation method that uses a Lloyd mirror (see document (11)) and that is illustrated in Figure 12, can also be used. A second return mirror symmetric to the Lloyd mirror about the center of the grating, and a CCD camera type position system sensitive to ultraviolet radiation and particularly to the writing wavelength (244 nm in our case) is used to display and adjust the writing beams, in order to provide more flexibility in adjusting the parameters.

A Bragg grating can be written into an optical fiber 36 by photosensitivity, advantageously making use of an frequency doubled argon laser 50 that emits a beam 52 with a wavelength of 244 nm, but other laser lines or even other lasers can also be used such as a KrF excimer laser or a neodymium doped YAG laser quadrupled in frequency.



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The beam 52 is reflected by a series of mirrors such as mirror 54 and is then filtered and stretched by two telescopes, one spherical 56 and the other cylindrical 58 after passing through a periscope 60.

5 The beam then passes through the phase splitter 42 placed on a support device 61 with several degrees of freedom. The beam, in which the wave front has been modified, is then focused by a cylindrical lens 62 in the core of the optical fiber 36. This fiber is

10 located at the edge of the Lloyd mirror 64 that "folds" the two half-parts of the beam on themselves. Thus, the beam creates interferences focused in the fiber core over a length defined by the position of a cover 66. The cylindrical lens 62 and mirror 64 are placed

15 on two rotation plates 63 and 65 respectively that can advantageously be motor-driven. Their orientation with respect to the beam defines the Bragg wavelength of the written grating. Note that the polarization of the laser beam is vertical (normal to the work plane).

20 A second mirror 68, placed symmetrically with respect to the center of the grating to be written, is used to display the distribution of intensity writing the grating. When the beam is focused slightly above the fiber, the second mirror returns a divergent beam

25 similar to the beam that is propagated without reflection. These two parts of the beam are collimated by a cylindrical lens acting as the inverse of the lens 62 and are finally analyzed by a CCD camera 72 fitted with an objective 74 with an appropriate magnification.

30 The distribution of intensity in the plane of the CCD camera is characteristic of the envelope of the

intensity distribution of the two half parts of the beam on the focusing line at the Lloyd mirror. Provided that the Fresnel diffraction effect between the grating and the camera can be corrected, this  
5 distribution can be used to determine the envelope of the beam intensity generating the Bragg grating. This setup property is used to adjust the position in the grating of the phase skip(s) (using the y degree of freedom), with optimum control due to the diffraction  
10 pattern generated by edge effects related to each thickness change in the phase splitter. When this adjustment has been made, the laser beam is focused in the optical fiber and writing the required Bragg grating can begin.

15 We will now describe several applications of the invention for making Bragg grating devices.

A. The invention is applicable to the manufacture of phase skip Bragg gratings, at high spectral selectivity.

20 One of the improvements to the Bragg grating was to demonstrate a thin secondary transmission band, called the second transmission peak, in the reflected wavelength. Thus, the corresponding component, usually called a "phase skip Bragg grating", transmits a very  
25 specific wavelength from the initial spectrum of the guided wave in the reflected wavelength band (see Figure 13, to be compared with Figure 1).

There are many applications of this type of component in the various fields in which conventional  
30 Bragg gratings are used. It can be used for the manufacture of matchable lasers and laser diodes. It

can also be used in wavelength multiplexing and demultiplexing systems. Furthermore its very good wavelength selectivity makes it a more efficient transducer than conventional gratings. Finally, it  
 5 forms a new component with its own characteristics that can easily be applied to solve many guided optics problems.

Several techniques have been developed to make this second transmission peak. All use the basic  
 10 principle of a phase mismatch between two parts of a conventional Bragg grating. The guided wave 76 (Figure 14) that passes through a conventional Bragg grating 78 is reflected around the Bragg wavelength  $\lambda_{\text{Bragg}}$  since the modulation with period  $\Lambda$  that forms the grating makes a  
 15 distributed reflection of the wave in phase around a resonance wavelength (in other words  $\lambda_{\text{Bragg}}$ ) given by the relation  $\lambda_{\text{Bragg}} = 2n\Lambda$ . A constructive interference phenomenon occurs throughout the length of the grating.

If a phase change is formed at the center of this  
 20 type of conventional grating ( $n$  = effective mode index) the two halves of this grating interfere with each other destructively. The wavelength thus selected can no longer be reflected and is transmitted in the second peak. If the transmission is to take place at  $\lambda_{\text{Bragg}}$ ,  
 25 the two parts that interfere must "see" a total phase shift  $\Delta\phi$  equal to  $\pi$  (modulo  $2\pi$ ), which is the reason for the name " $\pi$  phase skip Bragg grating".

The desired effect can be obtained if a resonant cavity 80 with a length such that the total induced  
 30 phase shift is equal to  $\pi$ , is inserted in the middle of

the grating. Thus, we usually consider a phase skip of  $\pi/2$ , the phase shift due to passing through the cavity. We can consider a phase shift of  $\lambda/4$ , the value of the optical width of the cavity necessary to produce a forward-return phase shift equal to  $\pi$ .

We can also form a phase change grating. In this case, the phase mismatch is no longer due to a cavity but is due to a change in the phase of the periodic modulation that forms the grating. The result is then identical; a transmission peak appears at the Bragg wavelength for two modulations with a phase difference  $\pi$  with respect to each other. The form of the index modulation for the case of an amplitude index modulation  $\Delta n_0$  with period  $\Lambda$  along an abscissa  $z$  and for a grating of length  $L$ , and a phase shift at the center equal to  $\Delta\Phi$ , is as follows:

$$\Delta n(z) = \Delta n_0 \cdot \cos\left(\frac{2\pi}{\Lambda}z + \Phi_1\right) \text{ for } 0 < z < \frac{L}{2}$$

$$\Delta n(z) = \Delta n_0 \cdot \cos\left(\frac{2\pi}{\Lambda}z + \Phi_1 + \Delta\Phi\right) \text{ for } \frac{L}{2} < z < L$$

We will now study the spectral response of a phase skip Bragg grating. We will consider the case of a periodic modulation of the propagation index in the core of an optical fiber. The index modulation is represented by the following formula:

$$\Delta n(z) = \Delta n_0 \cdot \cos\left(\frac{2\pi}{\Lambda}z + \Phi(z)\right)$$

where  $\Phi(z) = 0$  for  $0 < z < z_t$  and  $\Phi(z) = \Delta\Phi$  for  $z_t < z < z_f$ .

We will now consider the propagation and counter-propagation modes  $A^+$  and  $A^-$ . The index modulation will

act as a disturbance causing coupling between the two modes. This will be represented by the following coupling equations:

$$\begin{aligned} \frac{dA^-}{dz} &= j\Omega A^+ e^{j[2\Delta\beta \cdot z + \Phi(z)]} \\ 5 \quad \frac{dA^+}{dz} &= j\Omega A^- e^{j[2\Delta\beta \cdot z + \Phi(z)]} \end{aligned}$$

$\Omega$  is the coupling coefficient at wavelength  $\lambda$  in a fiber with a confinement factor  $\eta$  (proportion of energy guided in the core and interacting with the grating):

$$\Omega = \frac{\pi \Delta n_0}{\lambda} \eta$$

10  $\Delta\beta$  represents the phase match between the propagation wavelength and the resonance wavelength (where  $n$  is the propagation index):  $\Delta\beta = \frac{2\pi}{\Lambda} - \frac{4\pi n}{\lambda}$ .

We will now consider the two conventional Bragg gratings adjacent to the abscissa  $z = z_t$  with a phase skip  $\Delta\Phi$ . The system of equations in the two areas is solved with the boundary conditions defined in Figure 15:

$$\begin{aligned} A_1^+(0) &= 1 & A_2^-(z_f) &= 0 \\ A_1^+(z_t) &= A_2^+(z_t) & A_1^-(z_t) &= A_2^-(z_t) \end{aligned}$$

The value of  $|A_2^+(z_f)|^2$  then gives the expression for the spectral transmission of the grating as a function of the wavelength, the index modulation  $\Delta n_0$ , the phase shift  $\Delta\Phi$  and the lengths of the two areas  $l = z_t$  and  $l' = z_f - z_t$  respectively. It is demonstrated that the transmission of a single phase skip grating can be written:

$$T(\lambda, \Delta n_0, \Delta\Phi, l, l') = \frac{\gamma^4}{\Gamma^2 + (C_1 - \Gamma)[C_1 - \Gamma(1 - 2\cos(\Delta\Phi))] + C_2(C_2 - 2\Gamma\sin(\Delta\Phi))}$$

$$\begin{aligned} \text{where: } \gamma^2 &= \Omega^2 - \Delta\beta^2 & L &= l + l' \\ S &= \sinh(\gamma l) \cdot \sinh(\gamma l') & C_1 &= \gamma^2 \cosh(\gamma L) \\ \Gamma &= \Omega^2 S & C_2 &= \Delta\beta \sinh(\gamma L) \end{aligned}$$

It can easily be checked that the typical transmission formula for a uniform Bragg grating is  
 5 obtained for  $\Delta\Phi = 0$ .

If  $\Delta\Phi = \pi$  and  $l = l'$ , the formula is simplified to give:

$$T = \frac{\gamma^4}{\Delta\beta^2(\Delta\beta^2 \cosh^2(\gamma L) + \gamma^2 \sinh^2(\gamma L) - 2\Omega^2 \cos(\gamma L) + \Omega^4)}$$

Note that if the resonant wavelength,  $\Delta\beta = 0$  is  
 10 considered, the result is  $T = 1$  regardless of the values of  $\Delta n_0$  and  $L$ .

If  $\Delta\Phi = \pi$  and  $l \neq l'$ , the value of the transmission at the Bragg wavelength is no longer equal to one. The result is:

$$15 \quad T(\lambda_{\text{Bragg}}) = \frac{1}{\cosh^2[\Omega(l - l')]}$$

Thus, the transverse displacement of the phase splitter in the writing beam makes it possible to precisely define the value of the filter transmission coefficient at  $\lambda_{\text{Bragg}}$ .

20 If  $\Delta\Phi \neq \pi$ , the position of the secondary peak in transmission is no longer matched to the Bragg wavelength.

Different methods are known for manufacturing phase skip gratings, and particularly the method that

uses phase change masks. The method used in document (4) is spatial frequency doubling lithography (SFDL): firstly a grating is formed on a mask using the electron beam emission system (EBES), and the Bragg grating is then written in the guide by SFDL. Document (7) describes the phase skip Bragg grating written using the phase mask method. The mask is composed of a grating with a phase skip in its modulation period, which is transmitted by photosensitivity in the fiber core and the value of the phase skip in the Bragg grating is fixed by the value of the phase skip in the mask grating. With this second known method, the parameters cannot be modified directly and therefore the cost of a specific and limited implementation is very high since a mask has to be created for each spectral position of the grating.

We will now mention the advantages of the invention for making these phase skip gratings in optical fibers (but the invention is also applicable to integrated optical guides):

1. Good manufacturing "flexibility": the adjustment of the transfer function of the phase skip grating in transmission, namely the transmission level and the spectral position of the peak, is adjusted simply and in a decorrelated manner. The first adjustment (transmission) is made by offsetting the splitter with respect to the insolation wave half-front (degree of freedom y) and the second adjustment (spectral position) is made by rotating the splitter with respect to the beam

(degree of freedom  $\alpha$  or  $\theta$ ). The Bragg wavelength of the written grating is independent of the splitter. Therefore, the splitter can be used to produce the required spectrum at any position within the normal wavelength band for this type of application. This is the main advantage provided by the process according to the invention compared with the phase mask method. Furthermore, any type of grating can be written (for example a variable modulation pitch grating or an apodized grating) since the invention only influences the phase.

2. Control of the result; the different parameters are adjusted by moving the splitter (using rotation plates and translation plates, preferably motor-driven). Since these movements can be very precisely quantified, the instrument can give very good control of grating manufacture.

3. Reproducibility of the manufacturing process is just as good as for a conventional Bragg grating written by an interferometric setup since a phase skip grating is produced in a single step.

4. Ease of use: it is very easy to use the instrument, it simply needs to be placed in the writing beam and the adjustment settings are made by moving plates. In the same way as for the phase mask method, the grating is written



in a single step, which is also an important advantage compared with other methods.

5           5. Production cost: the cost of the apparatus is not very high since it is not expensive to manufacture a phase splitter by deposition, and it is relatively easy to install it on a moving plate. Since the apparatus is also capable of writing all possible wavelengths, it can also be considered as being very cost effective. It  
10           is also economically attractive since it can be used to make other components.

Another advantage of this apparatus is related to its adaptation capabilities. It can thus be used to write Bragg phase skip gratings in optical fibers or in  
15   planar guides or even in semi-conductors. Since the splitter only influences the phase of the beam, modifications usually used for writing Bragg gratings (for example apodization of the spectral response in order to reduce secondary spectral lobes in the  
20   transmission spectrum) can be adapted to the writing process.

If several phase splitters are placed in the path of the beam, Bragg gratings with multiple phase skips can be written, the advantage of which has already been  
25   described (see document (13)).

For example, a Bragg phase skip grating has been written with the following characteristics; grating length = 10 nm; insolation power = 10 mW; optical fiber type = hydrogenated SMF28; writing duration = 10  
30   minutes. After writing, the spectrum was analyzed with a matchable source with a resolution of 1 pm. The

experimental plot agrees well with the theoretical plot obtained using the equations described above. The phase skip is determined by comparing the two plots.

B. The invention is also applicable to the  
5 manufacture of erasable Bragg gratings.

When writing a Bragg grating using an interferometric method like the methods described above, it is possible that the Bragg wavelength of the written grating is different from what is expected.  
10 This is due to the poor reproducibility of these methods (particularly due to uncertainty about knowledge of the real writing angle). It is possible that the characteristics of the written grating are not the same as were originally required, due to the lack  
15 of stability of the setup or due to a setting error or poor knowledge of the effective propagation index of the guide. In general, the fiber in which this grating is written must be sacrificed.

One elegant solution for solving this problem is  
20 to be able to erase gratings that do not have the originally expected characteristics. Thus, test gratings can be written in a fiber without altering its spectral properties. In this way, interferometric methods become more reproducible.

25 A Bragg grating written in a guide was considered. It can be represented by the following expression:

$$n(z) = n_0 + \Delta n_{\text{aver}} + \Delta n_0 \cdot \cos \left( \frac{2\pi}{\Lambda} z \right)$$

Suppose that a grating is then written identical to the previous grating at the same position, except

for a phase change equal to  $\pi$  over the grating length.  
The result is then:

$$n(z) = n_0 + \Delta n_{\text{aver}} + \Delta n_0 \cdot \cos\left(\frac{2\pi}{\Lambda} \cdot z\right) + \Delta n_{\text{aver}} - \Delta n_0 \cdot \cos\left(\frac{2\pi}{\Lambda} \cdot z\right) = n_0 + 2 \cdot \Delta n_{\text{aver}}$$

The modulation term has disappeared, and all that  
5 remains is an average increase in the index. If the  
transmission spectrum around the Bragg wavelength is  
observed, the filtering effect is no longer seen. The  
Bragg grating has been erased.

One possible practical solution would be to move  
10 the grating in translation by a half-period in order to  
rewrite a grating in phase opposition, but this would  
require the use of a translation plate with the  
precision of at least 0.1 micrometers (the interference  
pitch is usually about 0.5  $\mu\text{m}$ ). Furthermore, the  
15 translation could degrade the focusing setting in the  
core.

The invention solves this problem in a very simple  
and inexpensive manner. The phase splitter is placed  
in the beam using the device with several degrees of  
20 freedom. The position of the phase skip is outside the  
grating such that the phase in the grating is constant.  
The grating is then written in the same way as if there  
had been no splitter. If the decision is made to erase  
the grating, then the device is ordered to translate  
25 the splitter to create a phase change of  $\pi$  over the  
entire grating. For example, for a Lloyd mirror  
grating, this is equivalent to placing the phase skip  
on the optical axis of the beam, to shift the two  
interfering parts out of phase by  $\pi$ . This then  
30 prolongs writing until the grating spectrum disappears.

The final effect is what could be called an opposite overwriting.

For example, a conventional Bragg grating with a length of 4 millimeters is written in an hydrogenated optical fiber ( $140 \times 10^5$  Pa for three weeks). At a given writing level, the device is moved in translation in order to over-write another grating identical to the first grating, in phase opposition. The reflection coefficient decreases after translation of the device to return to its initial value. The grating erase time is equal to the writing time, and a new grating can be written continuously once the previous grating has been completely erased.

We will now describe the advantage of the invention for making erasable gratings:

1. Good "flexibility": unlike the solution provided by translation, the setting in this case is independent of the value of the modulation pitch and therefore of the grating wavelength. Since only the phase is changed, this erasing principle can be applied to all sorts of gratings (for example chirped gratings) and phase skip gratings.
2. Control of the result: the phase change parameter is well-controlled due to the use of this apparatus. Very high precision is not necessary for translation of the splitter; 0.1 mm is sufficient. The grating can be erased with the required precision on the residual reflection value, provided that the variation of the spectrum can be monitored in real time.

3. Reproducibility: reproducibility is not a problem in this case. Erasing can be done reproducibly since the phase shift is controlled.
- 5 4. Ease of use: there are no difficulties in erasing, provided that the change in spectral characteristics of the grating can be monitored in real time, since all that is necessary is a translation control on the splitter support device and closing of the laser beam at the right time.
- 10

Note that, due to the invention, the writing bench can be calibrated regularly without modifying the transmission spectrum of the fiber used to write the test grating.

15

Furthermore, erasing the grating is a means of obtaining a low reflection coefficient at the end of writing and not at the beginning. Thus, the focusing adjustment in the core has already been made and does not disturb growth of the grating.

20

C. The invention is also applicable to the production of Fabry-Perot cavity Bragg gratings.

A Fabry-Perot interferometer comprises a cavity delimited by two mirrors with reflection coefficients  $R_1$  and  $R_2$ . A matched resonance phenomenon occurs on the phase shift induced by the cavity when a light wave with wavelength  $\lambda$  penetrates into the cavity. When there are no losses in the two mirrors and  $R_1 = R_2 = R$ , the intensity at the output from the interferometer is in the following classical form:

25

30

$$I(\lambda) = \frac{1}{1 + \frac{4R}{(1-R)^2} \cdot \sin^2\left(\frac{2\pi}{\lambda} \cdot n_{\text{cavity}} \cdot e\right)}$$

$n_{\text{cavity}}$  is the intra-cavity index assumed to be equal to one for the case of two mirrors in air and  $e$  is the width of the cavity. The response as a number of waves ( $\sigma = 1/\lambda$ ) is a periodic function corresponding to a comb. The interval between two peaks (or a free spectral interval denoted ISL) is given by the relation:

$$\Delta\sigma = \frac{1}{2 \cdot n_{\text{cavity}} \cdot e}$$

10 The thinness of the lines depends on the value of the reflection coefficient from the two mirrors and their height depends on the difference between the two reflection coefficients.

A Bragg grating may be considered like a mirror about its resonant wave length. It reflects a spectral band with a given reflection coefficient. If two Bragg gratings with the same period are put one after the other, then a Fabry-Perot cavity is created. In the example of application A, a single secondary peak was added. A series of peaks can be added into the band reflected by the complete set of the two gratings by adjusting the distance  $e$  between the two gratings.

20 The fact that a Bragg grating is not a plane reflector like a mirror, but is rather a reflector distributed over its entire length, implies that the free spectral interval of a Fabry-Perot cavity grating is not constant.

The cavity can be made by opposite overwriting. Consider a Bragg grating with an index modulation amplitude  $\Delta n_0/2$  with a phase change of  $\pi$  at abscissa  $z = z_1$ . The total length of the initial grating is denoted  $L$ , the modulation period is denoted  $\Lambda$ , and the final average index variation is denoted  $\Delta n_{\text{aver}}$ . This grating can be represented by the following index change equation:

$$\begin{aligned} \Delta n_1(z) &= \frac{\Delta n_{\text{aver}}}{2} + \frac{\Delta n_0}{2} \cdot \cos\left(\frac{2\pi}{\Lambda} \cdot z\right) \text{ for } 0 \leq z \leq z_1 \\ \Delta n_1(z) &= \frac{\Delta n_{\text{aver}}}{2} + \frac{\Delta n_0}{2} \cdot \cos\left(\frac{2\pi}{\Lambda} \cdot z\right) \text{ for } z_1 \leq z \leq L \end{aligned}$$

Another grating identical to the first grating is considered but with a phase change at the abscissa  $z_2$  ( $z_1 \leq z_2$ ). Let  $\Delta n_2(z)$  be the representative function. The index modulation that will be obtained from the sum of these two variations is written as follows, with the two parts of the grating in phase opposition canceling each other out:

$$\begin{aligned} \Delta n(z) &= \Delta n_1(z) + \Delta n_2(z) = \Delta n_{\text{aver}} + \Delta n_0 \cdot \cos\left(\frac{2\pi}{\Lambda} \cdot z\right) && \text{for } 0 \leq z \leq z_1 \\ \Delta n(z) &= \Delta n_1(z) + \Delta n_2(z) = \Delta n_{\text{aver}} && \text{for } z_1 \leq z \leq z_2 \\ \Delta n(z) &= \Delta n_1(z) + \Delta n_2(z) = \Delta n_{\text{aver}} + \Delta n_0 \cdot \cos\left(\frac{2\pi}{\Lambda} \cdot z\right) && \text{for } z_2 \leq z \leq L \end{aligned}$$

If  $z_1 = \frac{L-e}{2}$  and  $z_2 = \frac{L+e}{2}$ , the result will be a Bragg grating with a Fabry-Perot cavity.

Different methods are known for manufacturing a Fabry-Perot cavity Bragg grating, particularly as

described in document (9) in which it is achieved by writing two successive Bragg gratings at a spacing equal to the length of the cavity. The match on the spectral interval and on the position of the peaks is  
5 obtained by uniform insolation of the cavity that modifies the value of the propagation index in this area. With this method, the Fabry-Perot cavity grating has to be written in three steps. In particular, it is necessary to write two successive gratings, which  
10 increases the manufacturing difficulty.

The invention can be used to make a Fabry-Perot cavity grating by opposite overwriting. The invention is a means of positioning a phase skip of  $\pi$  in a grating, an apparatus according to the invention needs  
15 to be placed at a certain abscissa during a time  $t_1$  and then at another abscissa during a time  $t_2$  in order to make a Fabry-Perot cavity.  $\Delta n(t)$  needs to be qualified during the experimental protocol for making the Fabry-Perot cavity Bragg grating, in order to determine the  
20 total writing time.

The first step is to determine the experimental conditions for the Fabry-Perot cavity grating to be written; the lengths  $l_1$  and  $l_2$  of the two Bragg gratings and their reflection coefficients  $R_1$  and  $R_2$ ,  
25 the length of cavity  $e$ , the fiber type and the insolation power. All these parameters are used to plot the spectrum using a matrix method (see document (12)) and thus to predict the shape of the spectral response of the Fabry-Perot cavity grating. The length  
30 of the cavity and the value of the average index change



need to be known to determine the free spectral interval. The following procedure can be used:

$\Delta n_0$  is deduced using the following relation:

$$\Delta n_0 = \frac{\lambda_{\text{Bragg}}}{\pi \cdot \eta \cdot l_i} \cdot \arg \tanh(\sqrt{R_i}) \text{ where } i = 1, 2$$

5 where  $\eta$  is the confinement factor for the wave guided in the core. The total length  $L$  of the grating is given by  $L = l_1 + e + l_2$ . There is a reflection coefficient  $R$  corresponding to this length  $L$  and this index modulation, given by:

10 
$$R = \tanh\left(\frac{\pi \cdot \Delta n_0}{\lambda_{\text{Bragg}}} \cdot \eta \cdot L\right)$$

Therefore, a grating with length  $L$  is written to obtain a reflection coefficient  $R$ . Let the measured insolation time be  $t_{\text{total}}$ . During this writing, the Bragg wavelength was offset by  $\Delta \lambda_{\text{Bragg}}$  corresponding to  
15 the increase in the value of the average index  $\Delta n_{\text{aver}}$ :

$$\Delta n_{\text{aver}} = \frac{\Delta \lambda_{\text{Bragg}}}{2 \cdot \Lambda}$$

The free spectral interval can thus be determined:

$$\Delta \sigma = \frac{1}{2 \cdot (n_0 + \Delta n_{\text{aver}}) \cdot e}$$

20 There are two possibilities if the value of the ISL is not suitable; either  $e$  can be changed and writing can be repeated to determine the new value of  $t_{\text{total}}$ , or the process can be continued and writing can be finished by a uniform insolation of the cavity which will have the effect of increasing the average index.

25 The insolation times for the two gratings with opposite phases are equal:  $t_1 = t_2 = \frac{t_{\text{total}}}{2}$ .

The first two test gratings can be erased using the method described above. We can now write the Fabry-Perot cavity grating. The phase skip is placed at a distance  $l_1$  from the edge of the grating using an apparatus conform with the invention, a grating is written for a time  $t_1$ , and the splitter is then moved by translation using its support device over a distance  $e$ , and writing is prolonged by a time  $t_2$ . The Fabry-Perot cavity Bragg grating is written.

We will describe the advantages of the invention for making this type of Bragg grating.

1. Manufacturing "flexibility": any Bragg wavelength can be written, in the same way as for the phase skip grating. The cavity length and the length of the two gratings is limited by the maximum size of a Bragg grating that can be written by the interferometric setup used. It is not limited by the apparatus, which includes a means of adjusting the length of the cavity with the precision possible by the adjustment in  $y$ . The reflection coefficients of these two gratings can be chosen by varying the total writing duration and the relative length of the two gratings. Therefore, it can be seen that most of the parameters are accessible with good "flexibility".

2. Reproducibility: there is no reproducibility problem related to the value of the wavelength of the two Bragg gratings since they have the same period. This is an advantage compared with known methods.

D. The invention is also applicable to the manufacture of a Bragg grating with a particular index modulation envelope.

The equation for a non-uniform Bragg grating can be written in the following form:

$$\Delta n(z) = \Delta n_{\text{aver}}(z) + \Delta n_{\text{mod}}(z) \cdot \cos\left(\frac{2\pi}{\Lambda} \cdot z\right)$$

$\Delta n_{\text{aver}}(z)$  is the average index distribution (as a function of the abscissa  $z$ ),  $\Delta n_{\text{mod}}(z)$  is the index modulation envelope of the Bragg grating, and  $\Lambda$  is the modulation period;

More sophisticated components can be obtained by making non-uniform gratings. For example, it is often desirable to apodize the gratings. The transmission spectrum of an apodized grating includes very small bounce on each side of the central peak, making it a particularly attractive component for all types of applications.

We will now consider the principle of dynamic phase shifted overwriting; we will use the basic principle presented in application examples B and C (successive writing of two gratings with parts in phase opposition), except for the difference that overwriting is done for variable times and for variable phase skip positions and values. Analytically, this is equivalent to considering a grating growth defined by the following relation:

$$\Delta n(z, T) = \int_0^T \left[ a(z, t) + b(z, t) \cdot \cos\left(\frac{2\pi}{\Lambda} \cdot z + \phi(z, t)\right) \right] dt$$

$$\text{where } a(z, t) = \frac{\partial \Delta n_{\text{aver}}}{\partial t}(z, t) \text{ and}$$

$$b(z,t) = \frac{\partial \Delta n_{\text{mod}}}{\partial t} (z,t)$$

5  $a(z,t)$  characterizes the growth kinetics of the average index change in the grating, depending on a large number of parameters (for example the insolation power and fiber type) and can be determined by studying the variation of the Bragg wavelength while writing a test grating.

10  $b(z,t)$  characterizes the growth kinetics of the index modulation envelope in the grating, and depends on many parameters and can be determined by studying the variation of the maximum reflection coefficient while writing a test grating.

15  $\Phi(z,t)$  is the function defined by the position and inclination of the splitter(s). This is a step function.

20 The variation of the average index cannot be modified using the invention. Therefore, we will only use the value of the index modulation:

$$\Delta n_{\text{per.}}(z,T) = \int_0^T \left[ b(z,t) \cdot \cos\left(\frac{2\pi}{\Lambda} \cdot z + \Phi(z,t)\right) \right] dt$$

We can write:

$$\begin{aligned} \Delta n_{\text{per.}}(z,T) = & \left\{ \int_0^T [b(z,t) \cdot \cos(\Phi(z,t))] dt \right\} \cdot \cos\left(\frac{2\pi}{\Lambda} \cdot z\right) \\ & - \left\{ \int_0^T [b(z,t) \cdot \sin(\Phi(z,t))] dt \right\} \cdot \sin\left(\frac{2\pi}{\Lambda} \cdot z\right) \end{aligned}$$

25

It can be seen that the modulation term is the sum of two amplitude modulations determined by the function

$\Phi(z,t)$ . A special application case is given when the value of  $\Phi$  is 0 or  $\pi$ . Firstly, we will consider a dynamic opposite overwriting with a single skip. We can define:

$$\begin{aligned} 5 \quad \Phi(z,t) &= \pi \text{ if } 0 \leq z \leq z_{\pi}(t) \\ \Phi(z,t) &= 0 \text{ if } z_{\pi}(t) \leq z \leq L \text{ (} L = \text{length of the} \\ &\text{Bragg grating).} \end{aligned}$$

The  $z_{\pi}(t)$  function defines the phase skip movement. The grating growth at abscissa  $z$  is a  
10 function of the phase shifted modulation time ( $t_{\pi}(z)$ ) or the unshifted modulation time ( $t_0(z)$ ) applied to the elementary part of the grating. The total writing time is denoted  $T$ . The final index modulation amplitude of the grating at abscissa  $z$  is denoted  $\Delta n_{\text{mod}}^T(z)$ . We can  
15 write:

$$\Delta n_{\text{mod}}^T(z) = \left| \int_0^{t_0(z)} b(z,t).dt - \int_{t_0(z)}^T b(z,t-t_0(z)).dt \right|$$

The standard modulation envelope  $A(z)$ , is defined as  $\Delta n_{\text{mod}}^T(z) = \Delta n_0 \times A(z)$ . In general, the minimum value of this function is denoted  $A_0$ .  $A(z)$  is the function to  
20 be obtained in the grating. This cannot be done unless the growth dynamics of the index modulation are known. It will be assumed that this growth function is known and is independent of the abscissa in the grating. We will set:

$$25 \quad \Delta n_{\text{mod}}(t_0) = \int_0^{t_0} b(t).dt$$

hence:

$$A(z) = \left| \frac{\Delta n_{\text{mod}}(T - t_0(z))}{\Delta n_0} - \frac{\Delta n_{\text{mod}}(t_0(z))}{\Delta n_0} \right|$$

Thus, there are two possible cases that correspond to two choices of the phase skip movement (move then rest or rest then move). These two movements give exactly the same result.

We will now consider the case:

$$A(z) = \frac{\Delta n_{\text{mod}}(T - t_0(z))}{\Delta n_0} - \frac{\Delta n_{\text{mod}}(t_0(z))}{\Delta n_0}$$

This choice defines the time interval of the phase skip movement:

$$A(z) \geq A_0 \text{ implies } \Delta n_{\text{mod}}(t_0(z)) \leq \Delta n_{\text{mod}}(T - t_0(z)) - \Delta n_0 \times A_0$$

which implies  $t_0(z) \leq t_{\text{sup}}$

$A(z) \geq 1$  implies  $\Delta n_{\text{mod}}(t_0(z)) \geq \Delta n_{\text{mod}}(T - t_0(z)) - \Delta n_0$  which implies  $t_0(z) \leq t_{\text{inf}}$

We can deduce:

$$z_{\pi}(t) = A^{-1}(1) \quad \text{for } 0 \leq t \leq t_{\text{inf}}$$

$$z_{\pi}(t) = A^{-1} \left[ \frac{\Delta n_{\text{mod}}(T - 1)}{\Delta n_0} - \frac{\Delta n_{\text{mod}}(t)}{\Delta n_0} \right] \quad \text{for}$$

$$t_{\text{inf}} \leq t \leq t_{\text{sup}}$$

$$z_{\pi}(t) = A^{-1}(A_0) \quad \text{for } t_{\text{sup}} \leq t \leq T.$$

Therefore, we can see that making an index modulation according to function  $A(z)$  in the case of a method with dynamic opposite overwriting with a single skip is only possible if  $A(z)$  is a reversible function.

If  $A(z)$  is not defined over a bijection interval, another method has to be applied. This interval has to be broken down into bijection parts. The number of phase skips to be placed in the beam is then equal to the number of the bijection intervals.

Let  $N$  be the number of bijections, and let  $i$  be the number of bijection interval of  $A(z)$   $[z_{i-1}; z_i]$ .

We can define  $\Delta n_0^i$ :  $\Delta n_0^i = \max(\Delta n_0.A(z))$  in  $[z_{i-1}; z_i]$  and  $A_i(z)$  as an application of  $[0; z_i - z_{i-1}]$  in  $[0; 1]$   
 5 which associates  $\frac{\Delta n_0}{\Delta n_0^i} \cdot A(z_{i-1} + Z)$  with  $z$ .

This problem is solved in the same way as in the case of a single skip. This is done by determining the movement of  $N$  phase skips by applying the formulas to series of functions  $Z_\pi^i(t)$  defined with respect to each  
 10 origin  $z_{i-1}$ . Therefore, regardless of the shape of  $A(z)$ , the dynamic opposite overwriting method with multiple skips can be used to produce the corresponding grating.

We will now consider the production of a  
 15 particular index modulation envelope according to the invention. The  $y$  translation of the splitter support device can be used to position the phase skip at any place in the grating. Therefore, a software controlled motor can control the movement  $z_n(t)$  and thus induce a  
 20 modification to the grating index modulation envelope.

If the function  $A(z)$  is not defined over a bijection interval, it is possible to place a series of devices provided with splitters in sequence to make the modification using the multiple skips method. In the  
 25 same way as for a single support device, the various motors can be controlled to make the component. This production requires precise knowledge of the grating growth function,  $\Delta n_{\text{mod}}(t)$ . This knowledge can be obtained by studying a test grating for which the

variation of the reflection factor is measured with respect to time. This measurement must be made at the same power as the power that will be used later to make a grating in the form  $A(z)$ . The required function is  
 5 deduced using the following relation:

$$\Delta n_{\text{mod}}(t) = \frac{\lambda_{\text{Bragg}}}{\pi \cdot \eta \cdot L} \cdot \arg \tanh(\sqrt{R(t)})$$

(see above for writing a Fabry-Perot cavity Bragg grating).

More simply, the function  $A(z)$  may be approximated  
 10 by assuming the growth of the modulation index to be linear with respect to time. In this case, the formulation of the equations is very much facilitated.

We will now describe the advantage of the invention for making a Bragg grating with a particular  
 15 index modulation envelope.

1. Manufacturing "flexibility": a Bragg grating with a constant or chirped spatial period can be written at any Bragg wavelength and any shape of index modulation or average index  
 20 envelope, provided that an appropriate number of support devices equipped with phase splitters are placed.
2. Ease of use: it is easy to produce the grating. All that is necessary is to measure  
 25 the growth function of a grating at a given power, and then to invert the function  $A(z)$  to be produced. Each splitter support device, with its control software installed on it, then manages displacement of the corresponding  
 30 splitter.



Note that the growth function of the modulation index with respect to time may be determined experimentally.

We will now give a few example applications.

5        The case of a linear approximation is considered, to describe them easily  $\Delta n_{\text{mod}}(t) = a.t.$

a) We can attempt to write a grating with a linear modulation envelope of the type shown in Figure 16. The phase skip movement for a linear approximation is  
10    defined as follows:

$$z_{\pi}(t) - \frac{2L}{T}.t \text{ for } 0 \leq t \leq \frac{T}{2} \text{ and}$$

$$z_{\pi}(t) = L \text{ for } \frac{T}{2} \leq t \leq T.$$

b) An attempt can be made to apodize a Bragg grating. A gaussian envelope is chosen:

15         $A(z) = \exp[-(z-L/2)^2/(L/N)^2]$

The shape of the grating when  $N = 4$  is as shown in Figure 17. This shape is used to apodize the grating, or more precisely its spectral response. The secondary lobes in the reflection spectrum for this grating are  
20    smaller than with a conventional grating.

In the example considered,  $A(z)$  is not defined over a bijection interval. Therefore, two functions are defined:

Interval 1:  $[0; L/2]:$

25         $A_1(z) = \exp[-(z-L/2)^2/(L/N)^2] \text{ for } z \text{ within } [0; L/2]$

$$A_0^1 = 0$$

$$A n_0^1 = \Delta n_{\text{mod}}(T)$$

Interval 2:  $[L/2; L]$

$$A_1(z) = \exp[-(z^2/L/N^2)] \text{ for } z \text{ within } [0; L/2]$$

$$A_0^2 = 0$$

$$A n_0^2 = \Delta n_{\text{mod}}(T)$$

We can deduce the movement of the two phase skips:

5 Interval 1:

$$z_\pi^1(t) = \frac{L}{2} \cdot \left[ 1 - \frac{2}{N} \cdot \sqrt{\ln\left(\frac{T}{T-2t}\right)} \right] \quad \text{for } 0 \leq t < \frac{T}{2}$$

$$z_\pi^1(t) = 0 \quad \text{for } \frac{T}{2} \leq t \leq T$$

Interval 2:

$$z_\pi^2(t) = \frac{L}{2} \cdot \left[ 1 - \frac{2}{N} \cdot \sqrt{\ln\left(\frac{T}{T-2t}\right)} \right] \quad \text{for } 0 \leq t < \frac{T}{2}$$

$$10 \quad z_\pi^2(t) = L \quad \text{for } \frac{T}{2} \leq t \leq T$$

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CLAIMS

1. Process for writing a Bragg grating in a transparent substrate (36) forming a light guide, particularly in an optical fiber, the Bragg grating forming a spectral filter with regard to a light wave that passes through it, process according to which the interference pattern between two light beams (28, 30) with the same wavelength and coherent with each other but with an angular offset, is transferred directly into the substrate due to a photosensitivity phenomenon within the same said substrate, this interference pattern being transferred in the substrate in the form of a modulation of the refraction index of this substrate, this process being characterized in that at least one of the said light beams is divided into at least two sub-beams offset in phase with respect to each other.

2. Process according to claim 1, in which the interference pattern is transferred according to an amplitude separation configuration.

3. Process according to claim 1, in which the interference pattern is transferred according to a wave front separation configuration.

4. Process according to any one of claims 1 to 3, in which the position of the phase shift or the value of this phase shift or the position and value of this

phase shift in the light beam formed by the two sub-beams, can be modified with time.

5        5. Apparatus for use of the writing process according to claim 1, this apparatus being characterized in that it comprises:

- 10        - at least one phase splitter (42) capable of creating a phase shift between at least two sub-beams, due to a difference in the optical path, and
- 15        - a means (61) of adjusting the position of the phase splitter, this adjustment means having at least two degrees of freedom, one being angular degree of freedom provided for adjustment of the value of the phase shift, and the other being a translation degree of freedom provided for adjustment of the position of the phase shift in the light beam formed by the two sub-beams.

20        6. Apparatus according to claim 5, also comprising interferometric means with two or three mirrors (32, 34) for transferring the interference pattern according to an amplitude separation configuration.

25

7. Apparatus according to claim 5, also comprising interferometric means with a prism (46) or a Lloyd folded mirror (64) for transferring the interference pattern according to a wave front separation configuration.

30

8. Phase skip Bragg grating with high spectral selectivity obtained by the process according to claim 1, the phase shift between the two sub-beams advantageously being equal to  $\pi$ .

5

9. Bragg grating obtained by the process according to claim 1, this Bragg grating being identical to a pre-written Bragg grating and being written on this pre-written grating, at the same  
10 position, with a phase change of  $\pi$  over the entire length of the pre-written grating, to erase all or some of the original grating in order to obtain a given reflection coefficient.

15 10. Fabry-Perot cavity delimited by two Bragg gratings at different positions in space, these two Bragg gratings being obtained by the process according to claim 1.

20 11. Bragg grating with a determined index modulation envelope, particularly an apodized Bragg grating, obtained by the process according to claim 1, by successively writing two Bragg gratings comprising parts in phase opposition, the time taken to overwrite  
25 one Bragg grating by the other being variable, to give a variable phase shift and a variable value of the phase shift.

30 12. Bragg grating according to claim 11, the position of the phase shift being displaced by a programmable movement.

ABSTRACT OF THE DISCLOSURE

PROCESS FOR WRITING BRAGG GRATINGS, APPARATUS FOR THE  
USE OF THIS PROCESS AND BRAGG GRATING DEVICES OBTAINED  
BY THIS PROCESS

Process for writing Bragg gratings, apparatus for using this process and Bragg grating devices obtained by this process.

According to the invention, a Bragg grating is  
5 written in a light guide (36) by transferring the  
interference pattern between two light beams (28, 30)  
with the same wavelength and coherent with each other  
but with an angular offset, directly into the substrate  
due to a photosensitivity phenomenon within the same  
10 said substrate, this interference pattern being  
transferred in the substrate in the form of a  
modulation of the refraction index of this substrate.  
At least one of the said light beams is divided into at  
least two sub-beams offset in phase with respect to  
15 each other.

Figure 10.



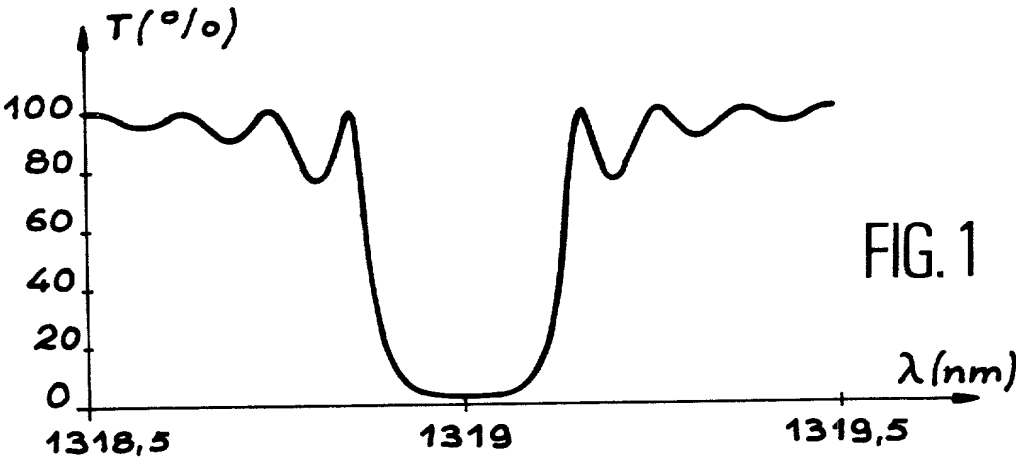


FIG. 1

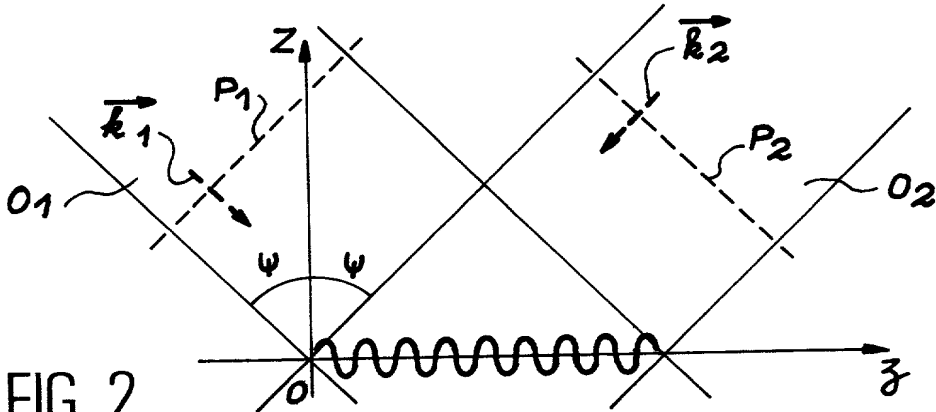


FIG. 2

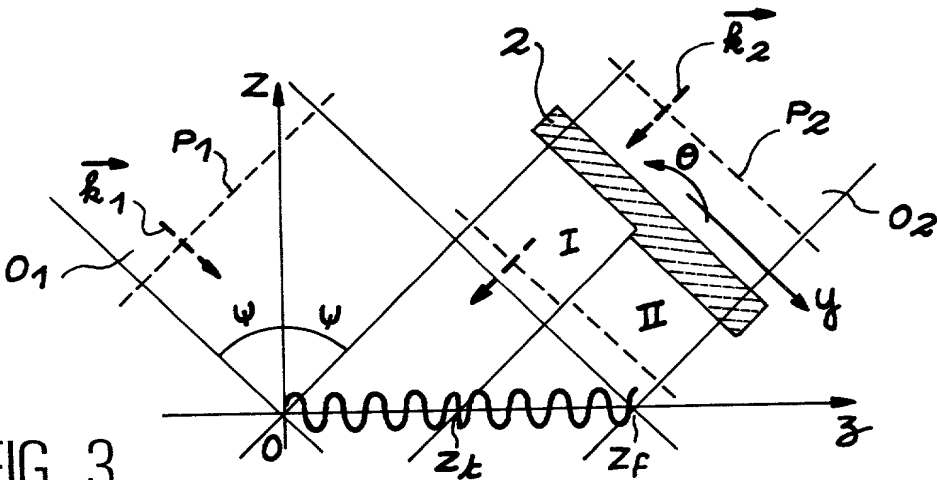


FIG. 3

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FIG. 4

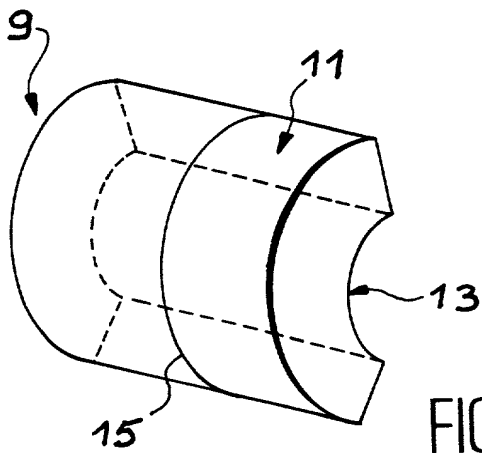
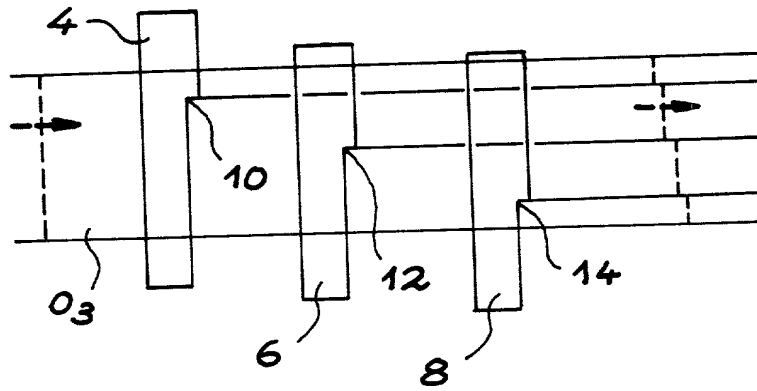


FIG. 5

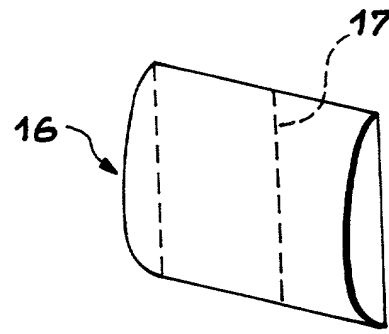


FIG. 6

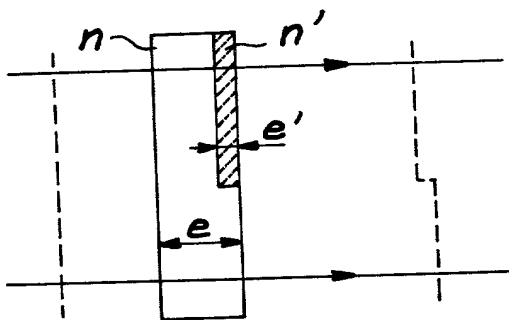
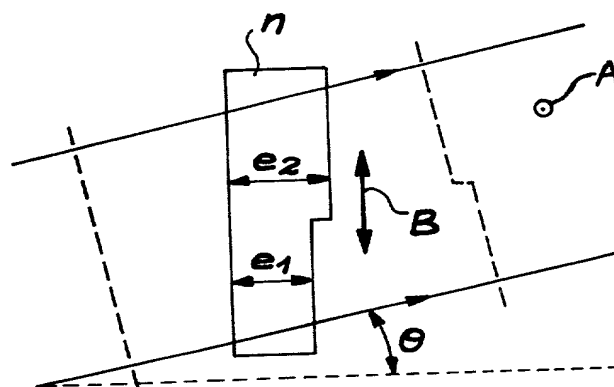


FIG. 7

FIG. 8



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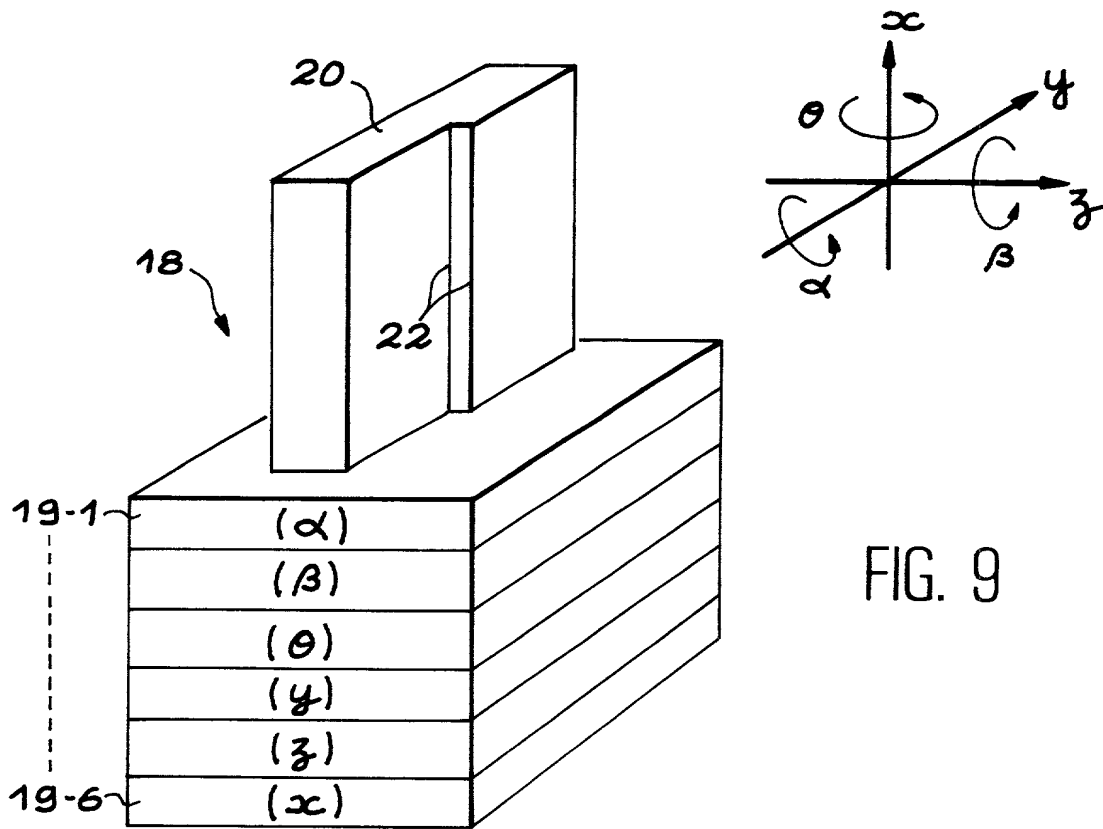


FIG. 9

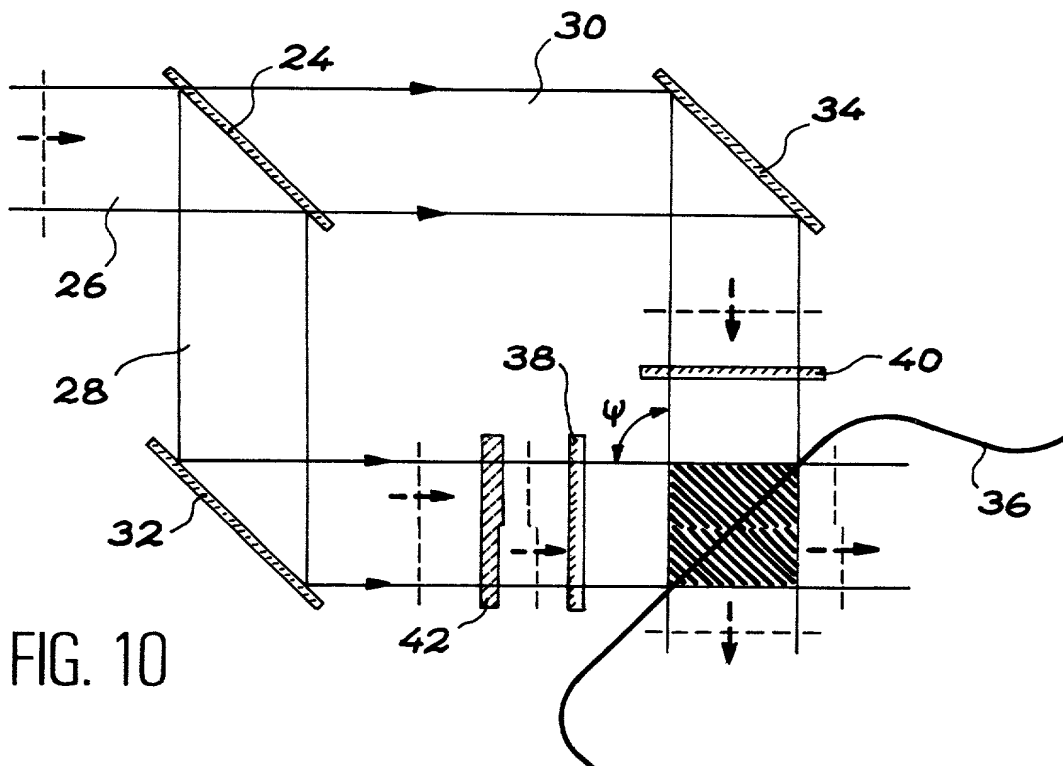


FIG. 10

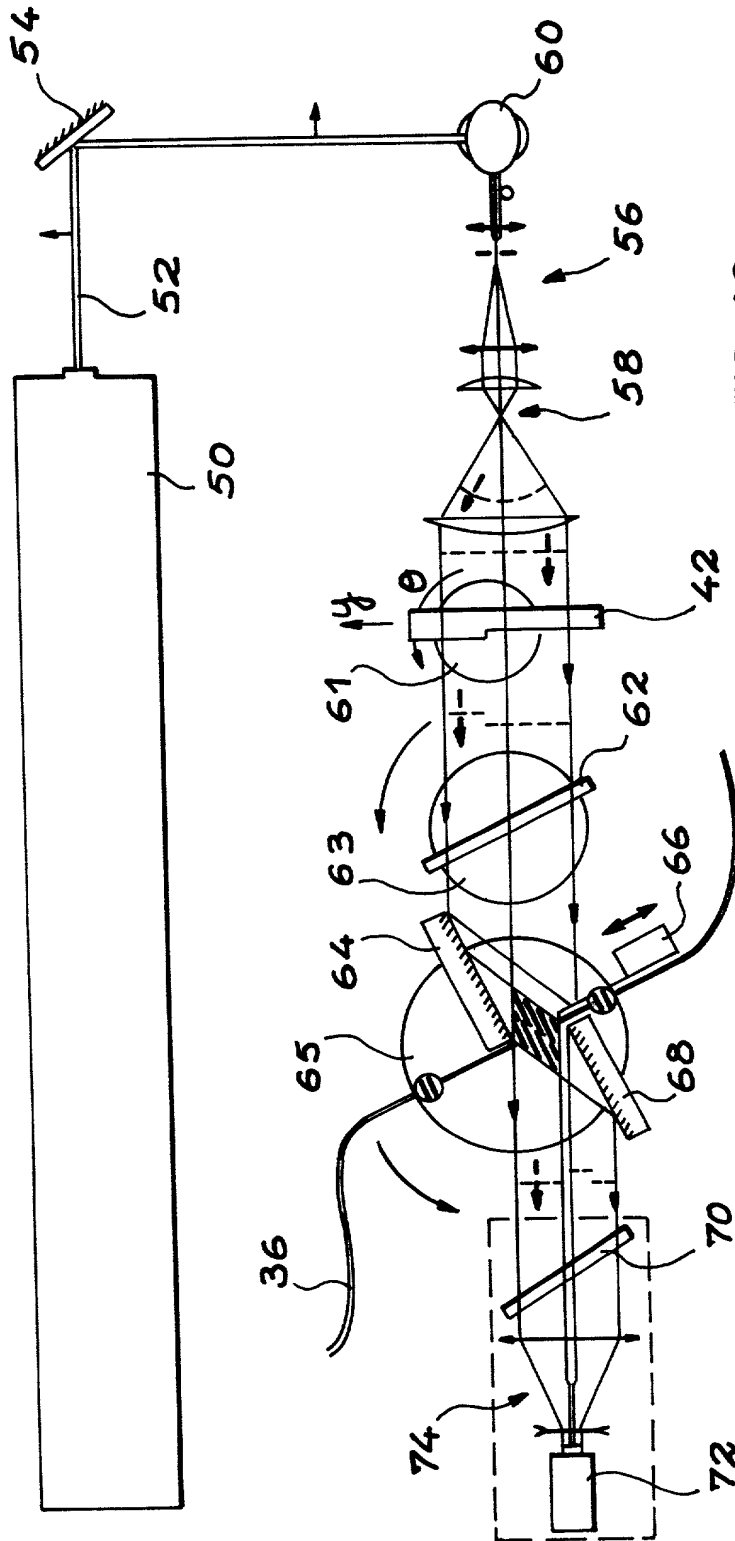
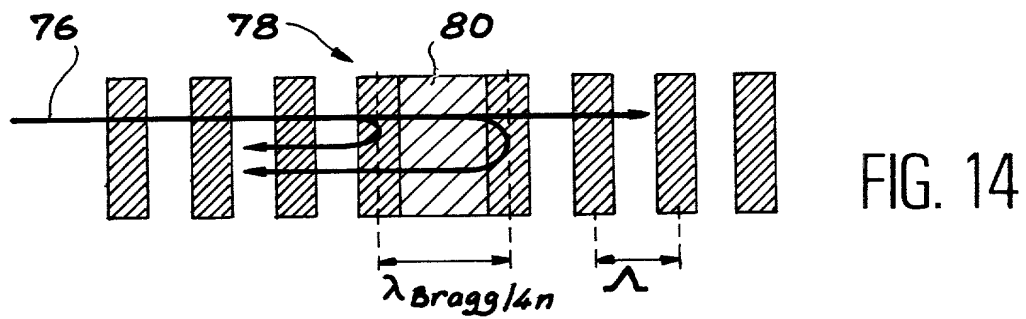
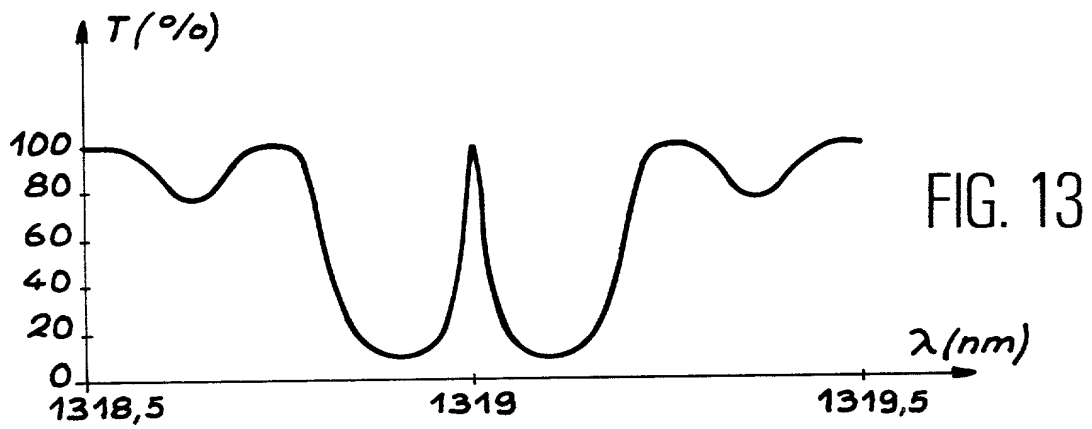
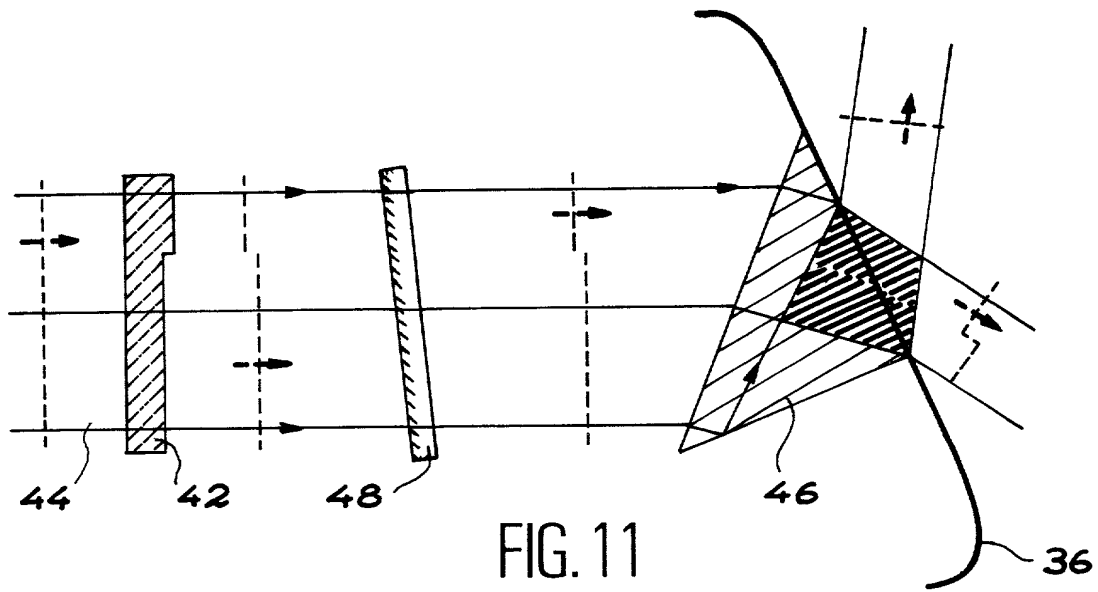


FIG. 12

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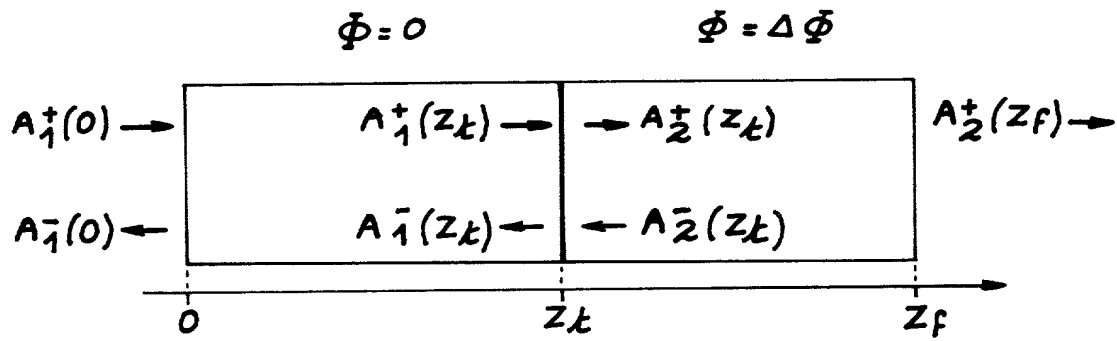


FIG. 15

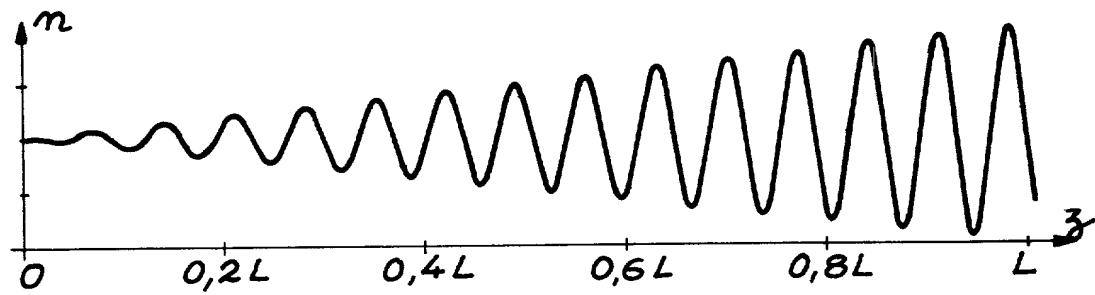


FIG. 16

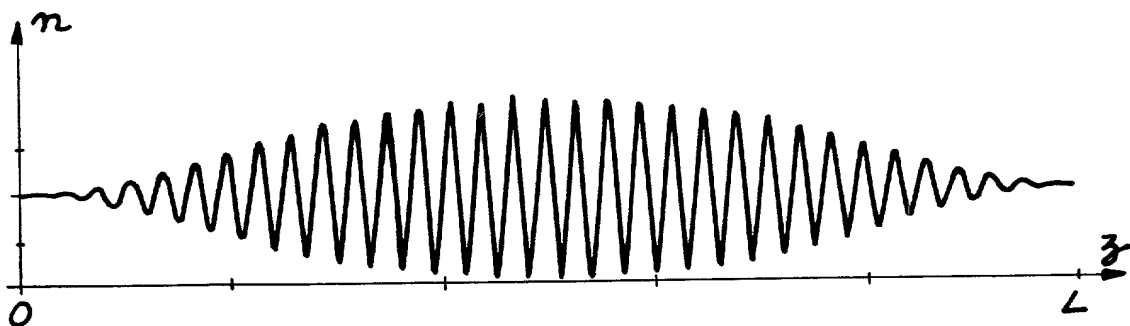


FIG. 17

# Declaration, Power Of Attorney and Petition

WE (I) the undersigned inventor(s), hereby declare(s) that :

My residence, post office address and citizenship are as stated below next to my name,

We (I) believe that we are (I am) the original, first, and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled

“PROCESS FOR WRITING BRAGG GRATINGS, APPARATUS FOR THE USE OF THIS PROCESS AND BRAGG GRATING DEVICES OBTAINED BY THIS PROCESS”

the specification of which

☐ is attached hereto.

☒ was filed on May 11, 1999

as Application Serial No. 09/700,182  
and amended on

☒ was filed as PCT international application

Number PCT/FR99/01119

on May 11, 1999

and was amended under PCT Article 19

on June 30, 2000

We (I) hereby state that we (I) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We (I) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

We (I) hereby claim foreign priority benefits under 35 U.S.C. § 119 (a)-(d) or § 365 (b) of any foreign application(s) for patent or inventor's certificate, or § 365 (a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed. Prior Foreign Application (s)

Application No.	Country	Day/month/Year	Priority Claimed	
98 05959	FRANCE	12 MAY 1998	<input checked="" type="checkbox"/> YES	<input type="checkbox"/> NO
_____	_____	_____	<input type="checkbox"/> YES	<input type="checkbox"/> NO
_____	_____	_____	<input type="checkbox"/> YES	<input type="checkbox"/> NO
_____	_____	_____	<input type="checkbox"/> YES	<input type="checkbox"/> NO

We (I) hereby claim the benefit under Title 35, United States Code, § 119 (e) of any United States provisional application(s) listed below.

(Application Number)

(Filing Date)

(Application Number)

(Filing Date)

We (I) hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of prior application and the national or PCT International filing date of this application.

Application Serial No.

Filing Date

Status (pending, patented,  
abandoned)

And we (I) hereby appoint : William L. Mathis, Registration Number 17,337; Robert S. Swecker, Registration Number 19,885; Platon N. Mandros, Registration Number 22,124; Benton S. Duffett Jr., Registration Number 22,030; Norman H. Stepno, Registration Number 22,716; Ronald L. Grudziecki, Registration Number 24,970; Frederick G. Michaud Jr, Registration Number 26,003; Alan E. Kopecki, Registration Number 25,813; Regis E. Slutter, Registration Number 26,999; Samuel C. Miller III, Registration Number 27,360; Robert G. Mukai, Registration Number 28,531; George A. Hovanec, Jr. Registration Number 28,223; James A. Labarre, Registration Number 28,632; E. Joseph Gess, Registration Number 28,510; R. Danny Huntington, Registration Number 27,903; Eric H. Weisblatt, Registration Number 30,505; James W. Peterson, Registration Number 26,057; Teresa Stanek REA, Registration Number 30,427; Robert E. Krebs, Registration Number 25,885; William C. Rowland, Registration Number 30,888; T. Gene Dillahunty, Registration Number 25,423; Patrick C. Keane, Registration Number 32,858; Bruce J. Böggs, Jr. Registration Number 32,344; William H. Benz, Registration Number 25,952; Peter K. Skiff, Registration Number 31,917; Richard J. McGrath, Registration Number 29,195; Matthew L. Schneider, Registration Number 32,814; Michael G. Savage, Registration Number 32,596; Gerald F. Swiss, Registration Number 30,113; Michael J. Ure, Registration Number 33,089; Charles F. Wieland III, Registration Number 33,096; Bruce T. Wieder, Registration Number 33,815; Todd R. Walters, Registration Number 34,040; Ronni S. Jillions, Registration Number 31,979; Harold R. Brown III, Registration Number 36,341; Allen R. Baum, Registration Number 36,086; Steven M. Du Bois, Registration Number 35,023; Brian P. O'Shaughnessy, Registration Number 32,747; Kenneth B. Leffler, Registration Number 36,075 and Fred W. Hathaway, Registration Number 32,236 our (my) attorneys, with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith; and we (I) hereby request that all correspondence regarding this application be sent to the firm of BURNS, DOANE, SWECKER & MATHIS LLP, whose post Office Address is : 1737 King Street #400, Alexandria, Virginia 22314-2727.

We (I) declare that all statements made herein of our (my) own knowledge are true and that all statements made on information and belief are believed to be true ; and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardise the validity of the application or any patent issuing thereon.

FERDINAND Pierre

NAME OF FIRST SOLE INVENTOR

Signature of Inventor

16 novembre 2000  
Date

Residence : 96 rue des Tartes de la résidence

73800 HOUILLLES FRANCE

Citizen of : France

Post Office Address : The same as residence



MAGNE Sylvain

20  
NAME OF SECOND INVENTOR

Signature of Inventor

16 novembre 2000

Date

Residence : 55 rue Marx Dormoy  
92260 Fontenay-aux-roses FRANCE

Citizen of : FRANCE

Post Office Address : The same as residence

MARTINEZ Christophe

NAME OF THIRD INVENTOR

Signature of Inventor

16 novembre 2000

Date

Residence : 33 rue de Paris

91120 Palaiseau  
FRANCE

Citizen of : France

Post Office Address : The same as residence

NAME OF FOURTH INVENTOR

Signature of Inventor

Date

Residence :

Citizen of :

Post Office Address : The same as residence

NAME OF FIFTH INVENTOR

Signature of Inventor

Date

Residence :

Citizen of :

Post Office Address : The same as residence